Meteorological Service of Canada: Ensemble Prediction System and Hydrologic Coupling R&D

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Global Environmental Multiscale Forecasting & Modelling System
2004-2014

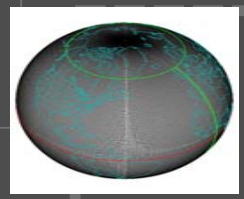
SPACE SCALE

Middle Atmosphere Model
&
Data assimilation

Multi- Seasonal Forecast

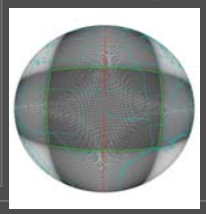
Monthly Forecast

Medium-range Forecast
(240 h, 15 to 100 km)
&
Data assimilation

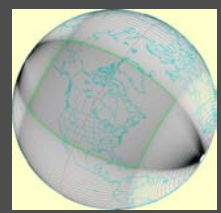


Ensemble Forecast

Regional and
Mesoscale Forecast
(24-48 h, 15-24 km)
&
Data assimilation



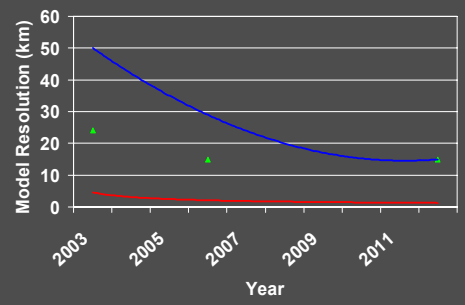
Regional Climate Model



Micro-
meteorology
(10m-1km)

Limited-Area Model
0-24h 1-4km
&
Data assimilation

TIME SCALE



Uniform resolution
Variable resolution
Hydrostatic
Nonhydrostatic
Global
Limited-area
Distributed memory

3D Var Data Assimilation
4D Var Data Assimilation
Ensemble Kalman Filter
Operational forecast
Emergency response
Volcanic ash
Air quality
Hydrologic coupling
Stratospheric ozone
Wave model
Oceanic coupling

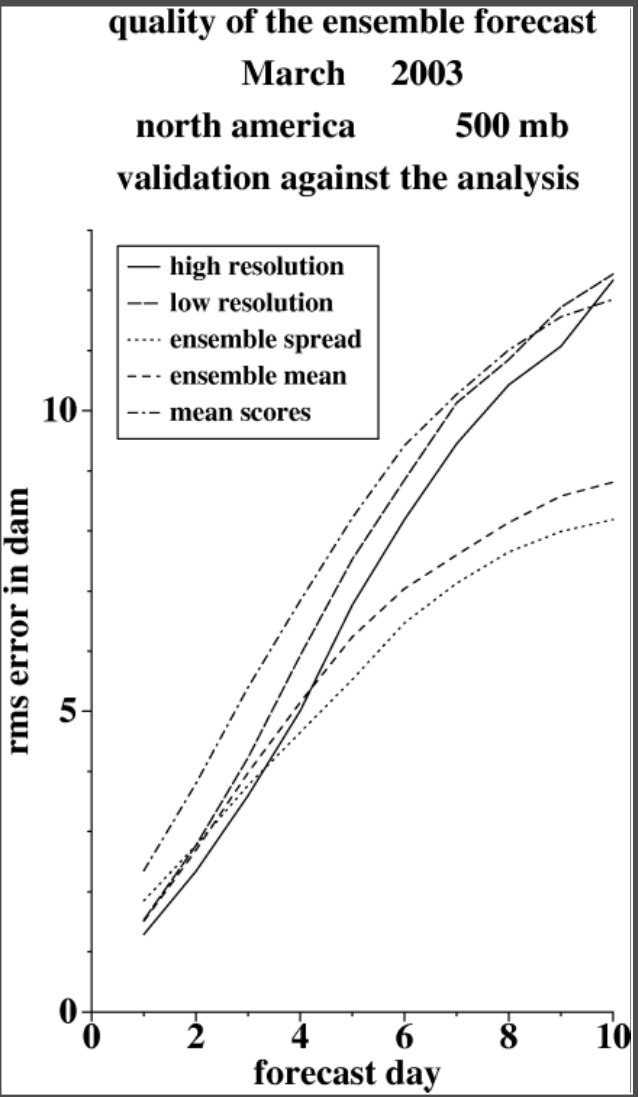
Global EPS

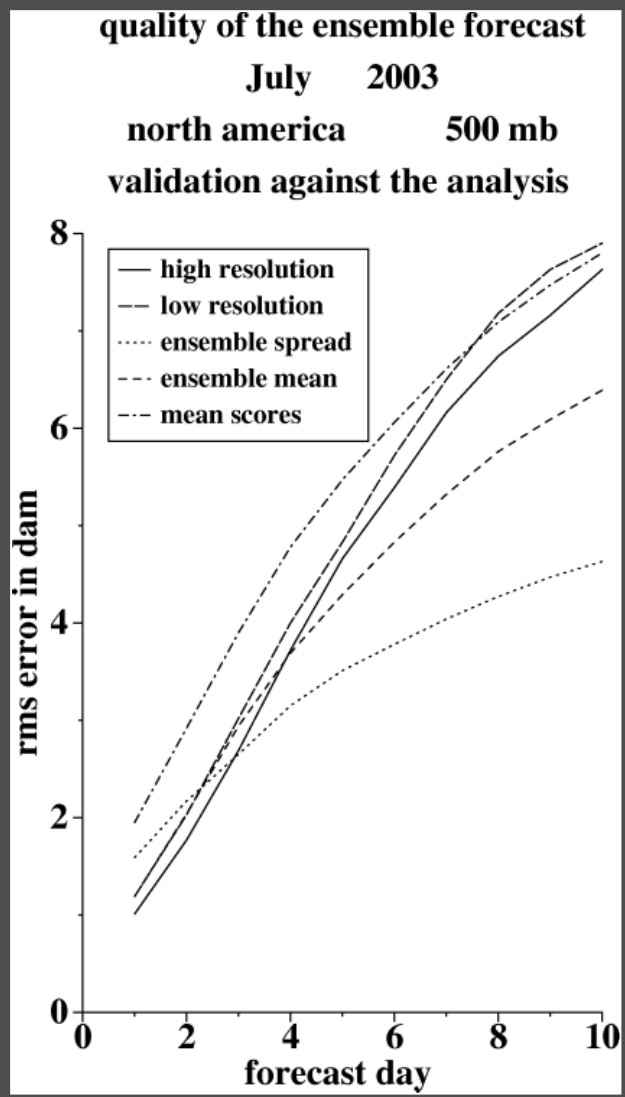
Thanks to Dr. P. Houtekamer,
L. Lefaivre, G. Pellerin and L. Wilson

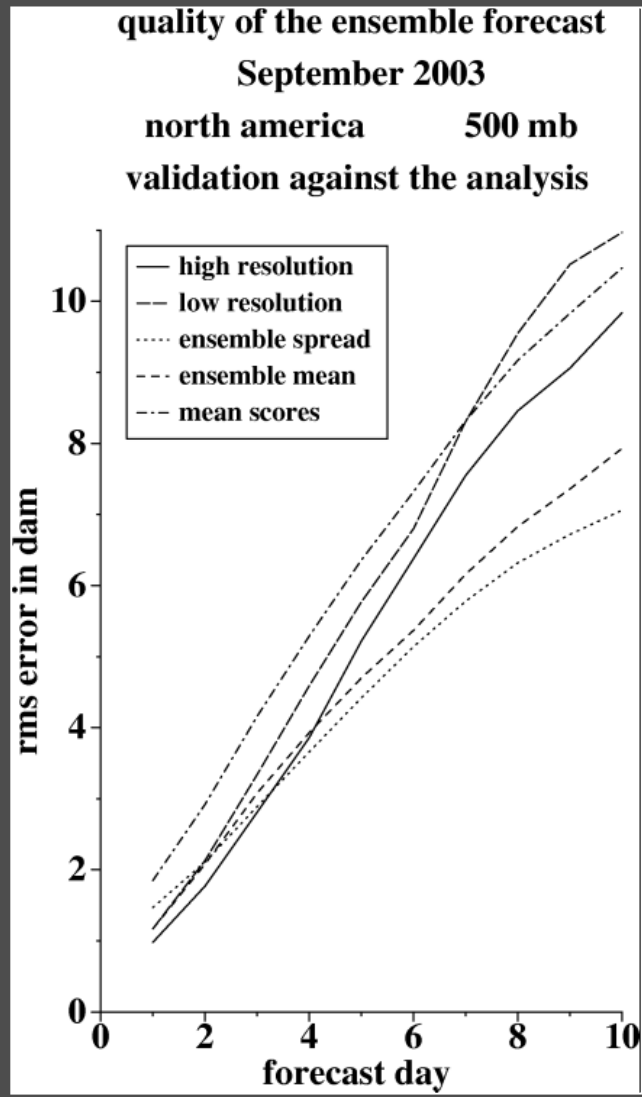
Now:

- 16 members (Multi-model: SEF T149 and GEM 1.2º)
- Perturbed analyses obtained from perturbed assimilation cycles (using OI scheme)
- Different model options used for both models
- Forecasts done once a day up to 10 days at 00 UTC

Verification







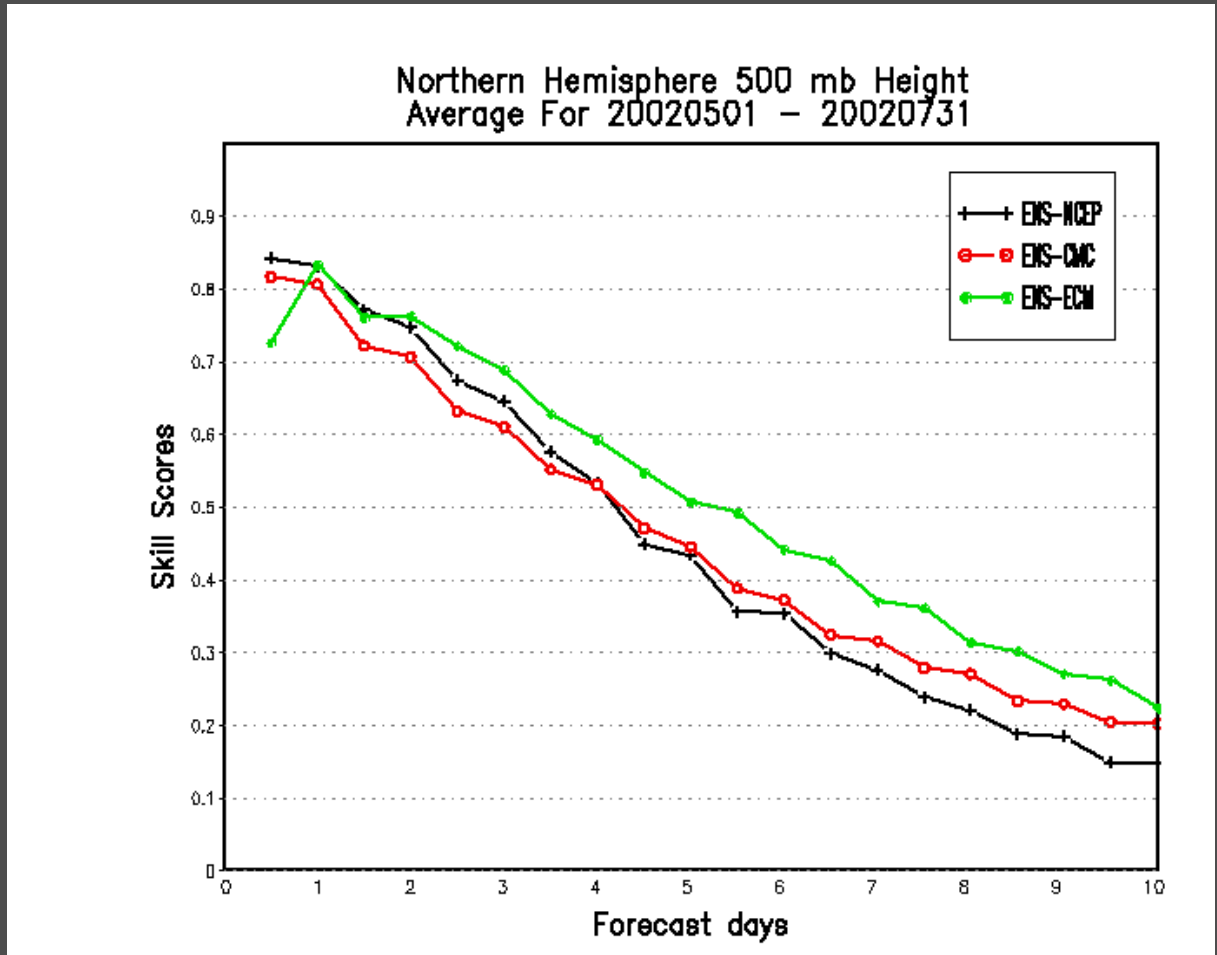
Verification comparison between ECMWF, NCEP and CMC EPS

The area under the relative operating characteristic curve (ROCA) measures the ability of a system to discriminate between hits and false alarms.

The ROCA skill score (ROCASS) is defined as:

ROCASS = 2*ROCA – 1

(ROCASS tends to 1 for a skilful system)



From Buizza, Houtekamer, Toth, et al , 2003

Short and long range plan for EPS

- Development of 7 day forecasts
- Development of week 2 forecasts
- Probabilistic forecasts for specialized users
- High impact weather forecasts

- 2004:

  - New data assimilation scheme (Ensemble Kalman Filter)
  - Forecasts run at 00Z **and** 12Z
  - Lead time up to 15 days
  - Increased number of members

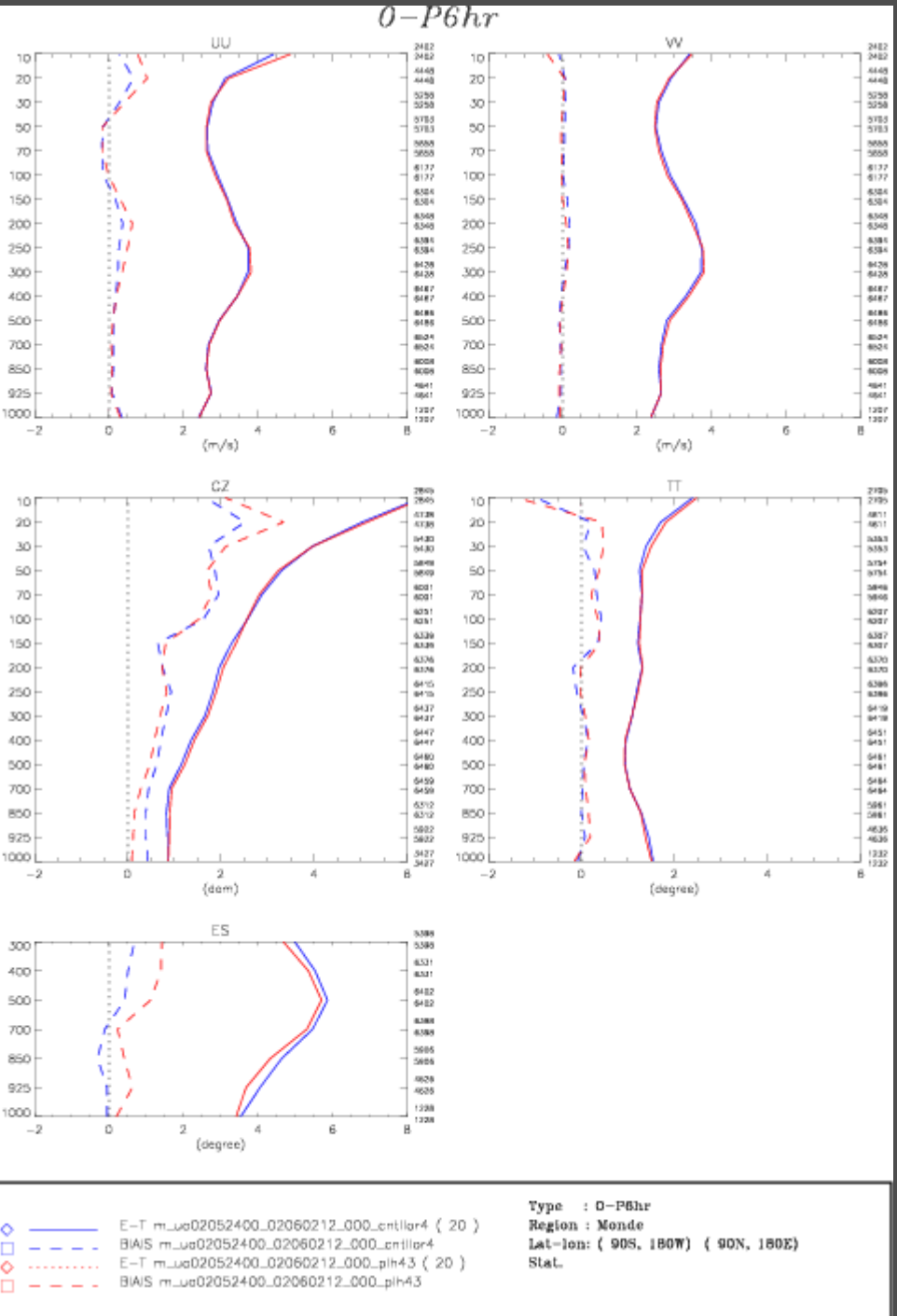
- Long range R&D plan:

  - Unified EPS with GEM model with a focus on physics perturbations

  - Short-range EPS system

  - Seamless EPS from short-range to seasonal time scale:

    * Validation and products could benefit from sharing expertise
    * Perturbation methodologies are different (different sources of predictability)



Agreement between the EnKF and the 3D-VAR

3D-VAR is in blue.
EnKF is in red.

For winds and temperature the EnKF and the 3D-VAR have remarkably similar innovation statistics.

For humidity the EnKF has a bigger bias but a smaller rms error.

Generally the scores are very similar. It would appear that the impact of the 4D aspect is small.

NCEP Collaboration - EPS

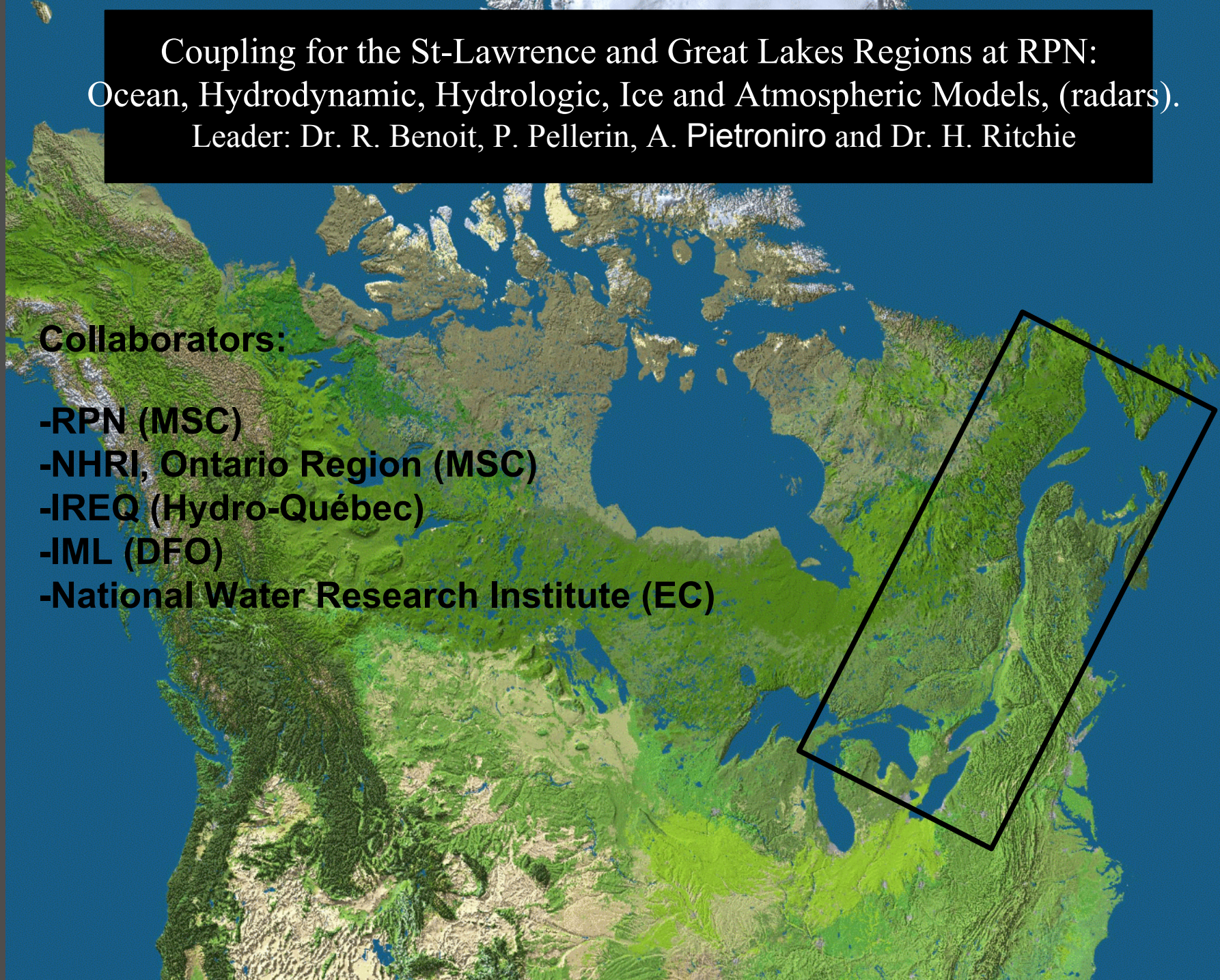
- Data exchange (standardized outputs)
  - Calibration of mean and variance of ensembles
  - Debiasing each model with a common methodology

- Common verification tools

- Moving to similar looking products
  - Probabilistic products for high impact weather
  - Products based on combined ensembles
  - Eventually, joint products and ensemble

Coupling for the St-Lawrence and Great Lakes Regions at RPN: Ocean, Hydrodynamic, Hydrologic, Ice and Atmospheric Models, (radars).

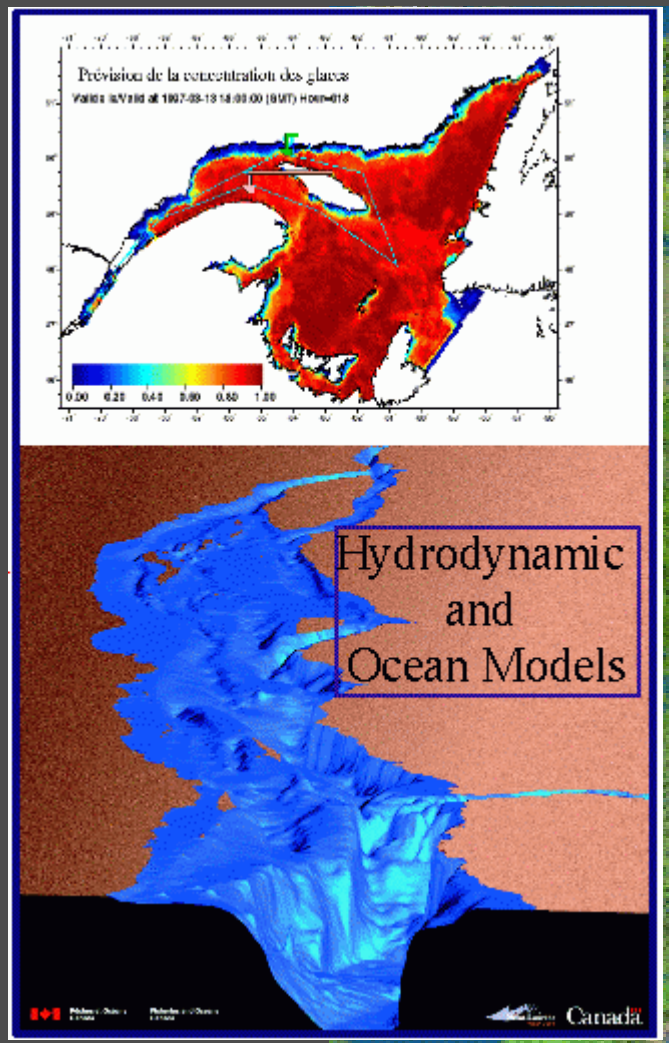
Leader: Dr. R. Benoit, P. Pellerin, A. Pietroniro and Dr. H. Ritchie



Collaborators:

-RPN (MSC)
-NHRI, Ontario Region (MSC)
-IREQ (Hydro-Québec)
-IML (DFO)
-National Water Research Institute (EC)

Coupling for the St-Lawrence:
Ocean, Hydrodynamic, Hydrologic and Atmospheric Models (radars).



- Ocean and Ice Models

- Operational Implementation 2004-2005

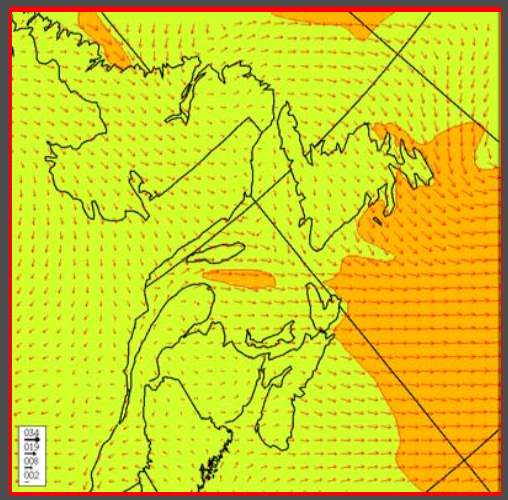
Environment Canada

Impact of a Two Way Coupling between an Atmospheric and an Ocean-Ice Model over the Gulf of St. Lawrence. Pellerin, Ritchie, Desjardins, Saucier and Roy, in MWR, 2003

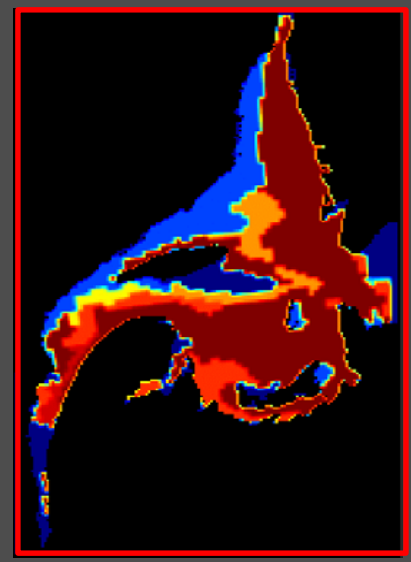
Coupler

Ice Fraction, Thickness and Temperature
Water Temperature .

Atmosphere



Ocean



Each: 600 seconds

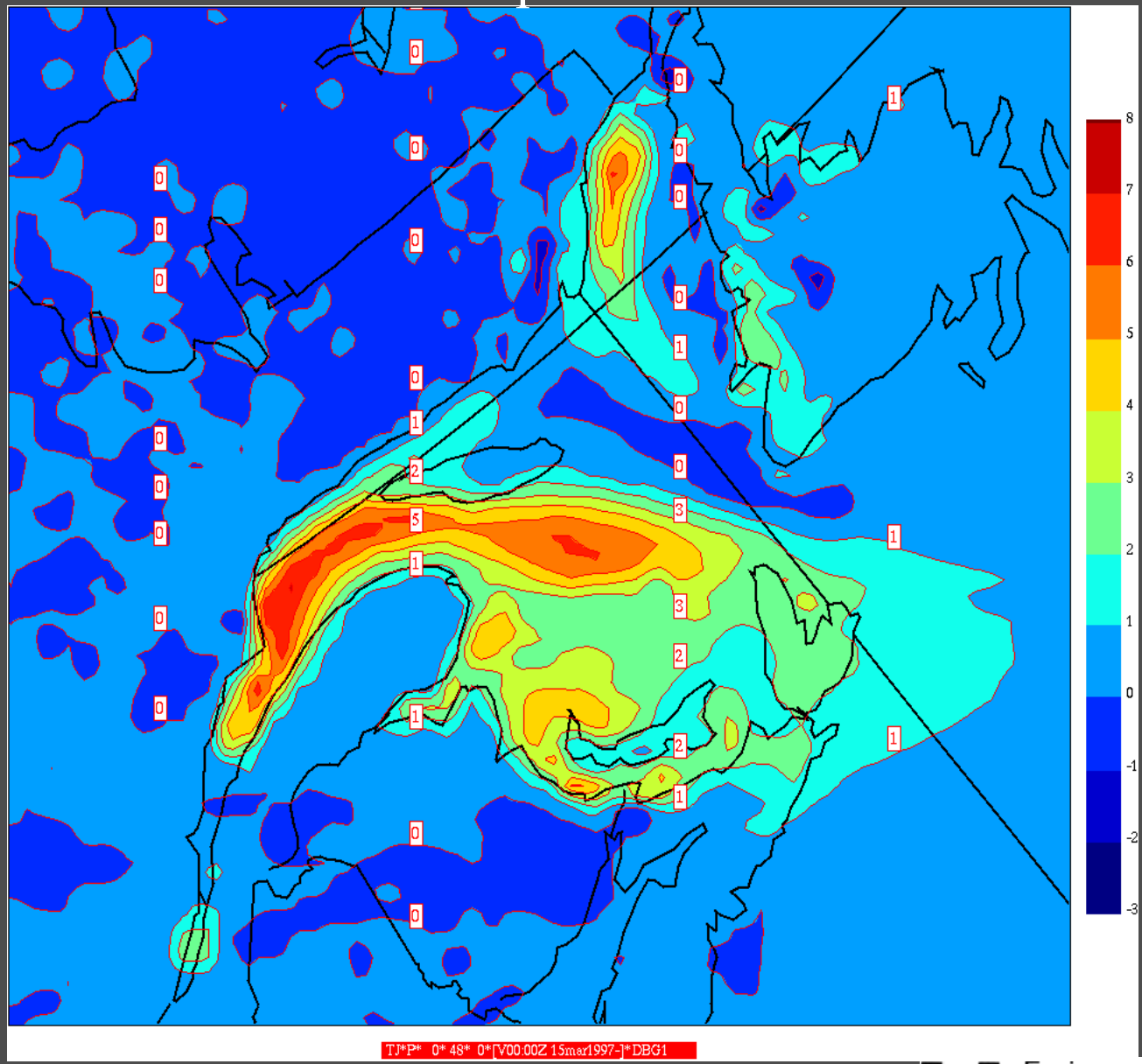
Coupler

IR and Vis flux, Humidity, Pressure, Winds
Precipitation.

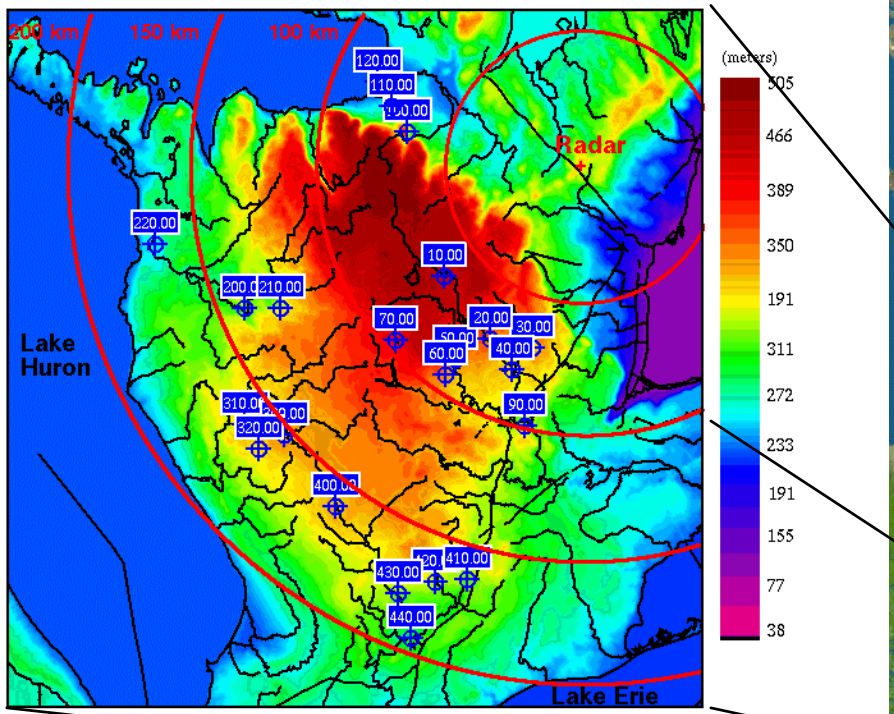
~4 km
timestep=50s

5 km
timestep=300s

2 way Coupling - 1 way Coupling
Surface temperature V 00Z 15



SW Ontario Watersheds



10 WALDERMAR	100 PINE R.	400 MITCHEL
20 SPD/ARMST MI	110 @ HOCKLEY	410 INGERSOLL
30 ERAMOSA/GUEL	120 NR. BAXTER	420 THAMESFORD
40 GUELPH	200 WALKERTON	430 THORNDALE
50 W. MONTROSE	210 HANOVER	440 EALING
60 ELMIRA	220 PT ELGIN	
70 CONEST/DRAYT	300 AB. WINGHAM	
80 GRND/MARSVIL	310 BL. WINGHAM	
90 GRND/GALT	320 BELGRAVE	

Hydrological model used and validated to do forecasts.

Radar

Observations

Ontario

Objective:

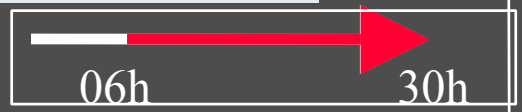
To try to understand a high resolution atmospheric forecast and thus to improve the use of the hydrological forecasts.

- **A series of experiments with atmospheric models (MC2, GEM, …) coupled with hydrological models (WATFLOOD, HYDROTEL, …).**
- **With radar or atmospheric model inputs, WATFLOOD outputs compare favorably well with measured streamflow for southern Ontario (Benoit et al., MWR 2000).**
- **The study being extended to other basins in collaboration with hydro-electricity industries.**

Example: Hydrological Coupling with MC2 at different resolutions: (35, 10 and 3km)

Atmospheric Model

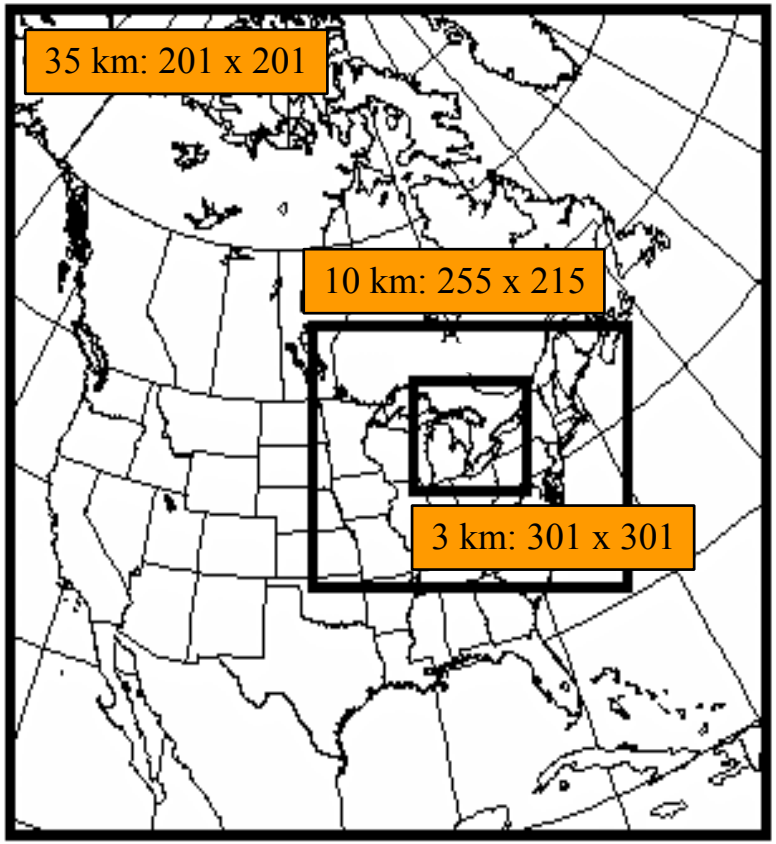
MC2
Non-hydrostatic
Full microphysics
Limited Area



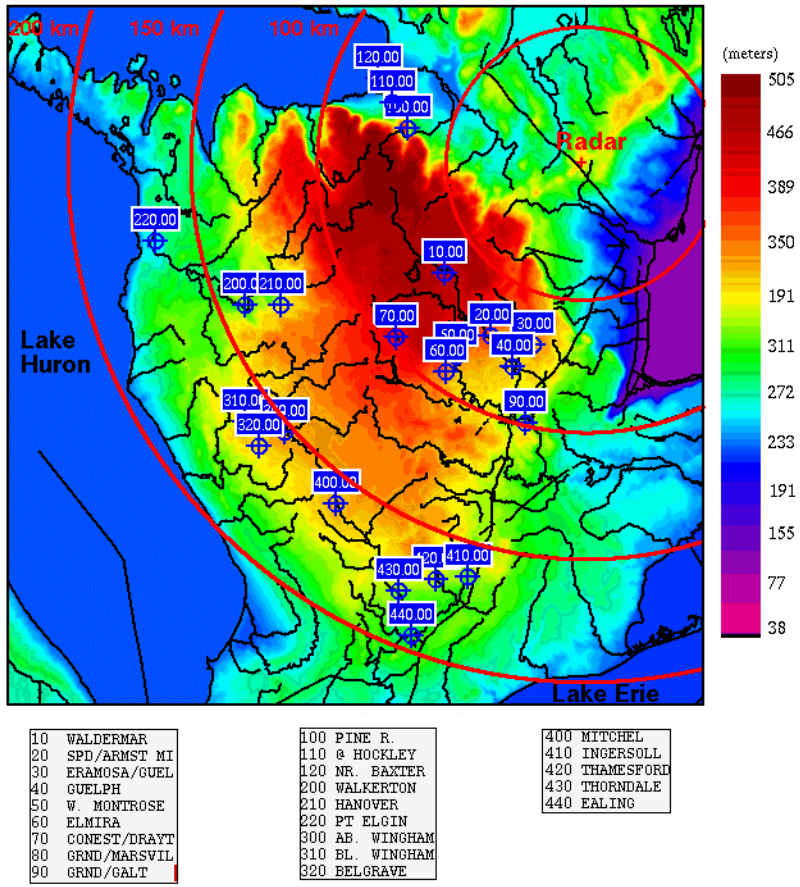
Hydrologic Model

- Watflood
- Distributed, physically based.

Grids



SW Ontario Watersheds



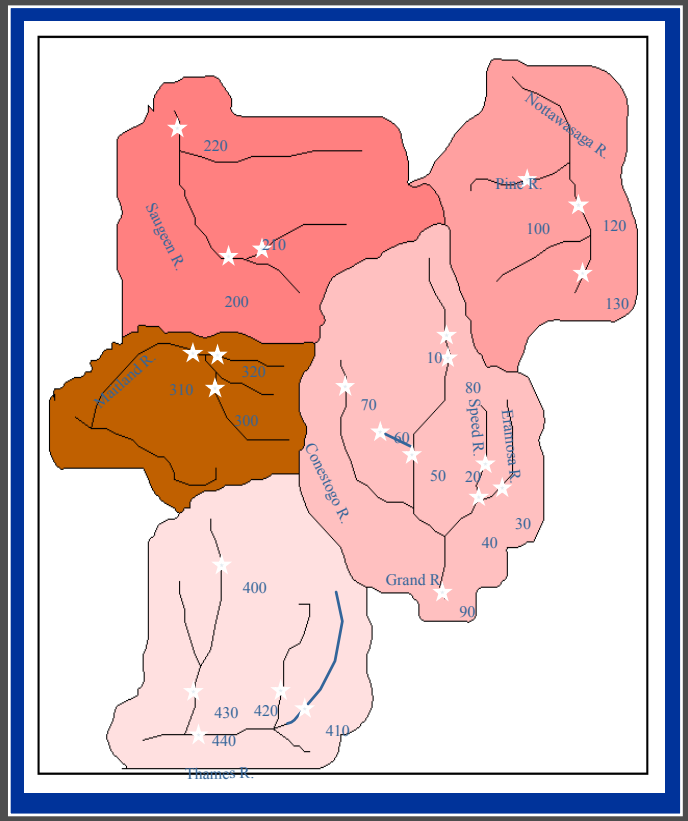
Hydrological Forecasts

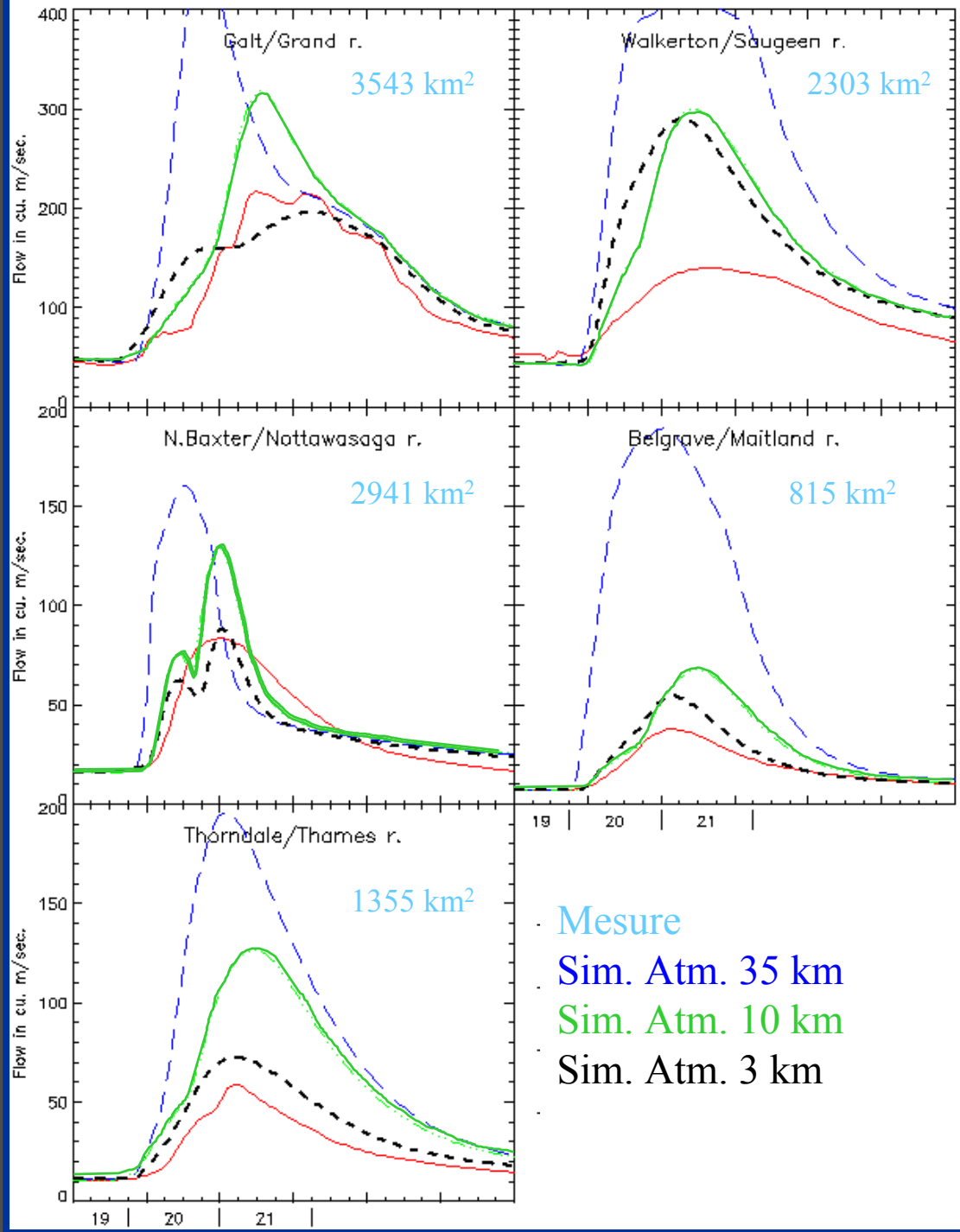
Comparisons of Spatial Resolutions: Atmospheric Forecasts

35 km

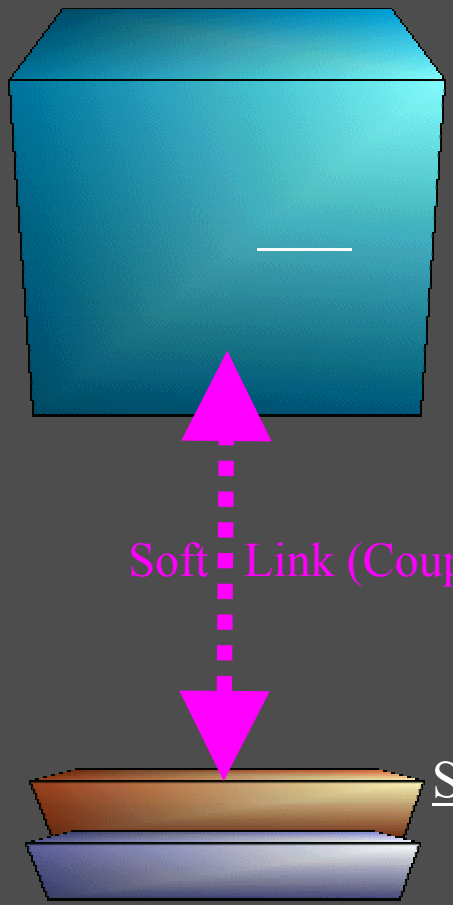
10 km

3 km





Plan for the Hydrological-Surface Coupling
To create a synergy for research and operations



- Atmospheric Model
- Radars
- Observations + Sat.

Soft Link (Coupler: GOSSIP, OASIS, …)

Surface Schemes (soil)

Hydrological Models

Multi-Users

- Governments
- Companies
- Universities
- Contries

Advantages

- To Improve Collaborations
- To Improve Validations and Calibrations.
- Preparation of the surface fields.
- Higher resolution than Atm. Model.
- More efficient
- ...

References
EPS

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- Houtekamer, P.L., L. Lefaivre, J. Derome, H. Ritchie, and H.L. Mitchell, 1996: A system simulation approach to ensemble prediction. Mon. Wea. Rev., 124, 1225-1242.
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- Pellerin, P., H. Ritchie, S. Desjardins, F. Saucier and Roy 2004: Impact of a Two Way Coupling between an Atmospheric and an Ocean-Ice Model over the Gulf of St. Lawrence. Mon. Wea. Rev.

Conclusion

- Expectations regarding environmental prediction in Canada increased dramatically and the market for weather and hydrological forecast products is segmented (e.g., farming community, municipalities, watershed authorities, etc.).
- Major trends in this decade included a shift away from measurements and the emerging view that advances in remote sensing and modeling could enhance significantly monitoring.
- In the modeling world, key developments included the integration of weather prediction models with land surface and hydrological models to produce soil moisture estimates, streamflow estimates and forecasts, etc.
- New initiative: Hydrometeorology and Arctic Laboratory (HAL) within the Meteorological Service of Canada.
- HAL will be co-located with the National Water Research Institute in Saskatoon
- EPS is needed for added value